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(63) Continuation-in-part of application No. 12/949,729, filed on Nov. 18, 2010, now Pat. No. 8,896,326.

Primary Examiner — Minh N Tang

(60) Provisional application No. 61/272,928, filed on Nov. 19, 2009.

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(57) **ABSTRACT**

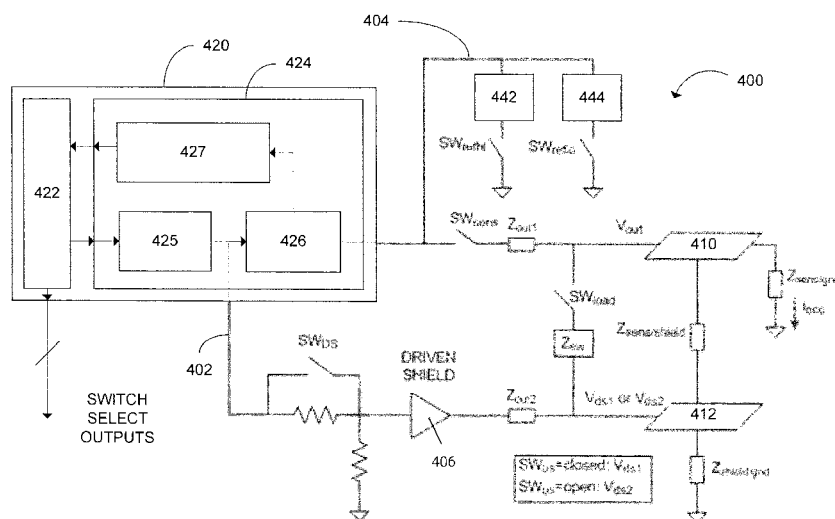
(52) **U.S. Cl.**  
CPC ..... *B60N 2/002* (2013.01); *B60R 21/0154*  
(2014.10); *B60R 21/01512* (2014.10); *B60R*  
*21/01532* (2014.10); *B60R 21/01544* (2013.01)

An occupant detection system includes a controller, a sensing electrode, and a shield electrode, the electrodes disposed in a vehicle seat. The controller is electrically coupled to the sensing electrode and shield electrode by a sensing circuit. The controller is configured to send an input signal to the sensing electrode, the shield electrode, or both and measures current, impedance, or capacitance values to determine the presence of an object on the seat, to classify the object, or both.

(58) **Field of Classification Search**  
None

## 2 Claims, 5 Drawing Sheets

See application file for complete search history.



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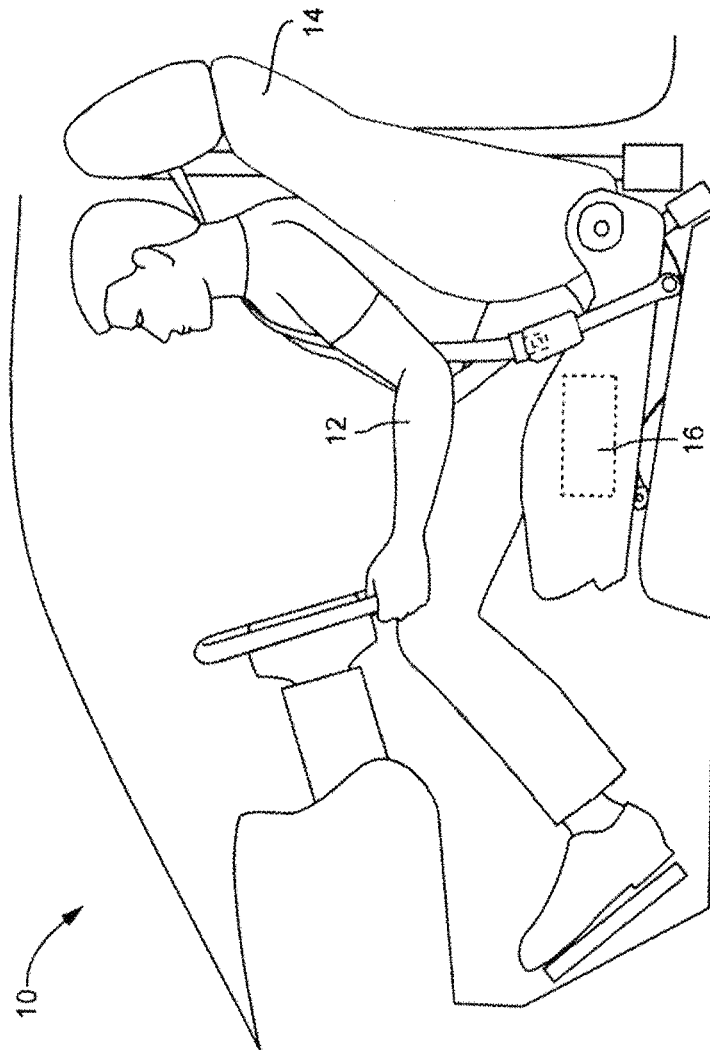
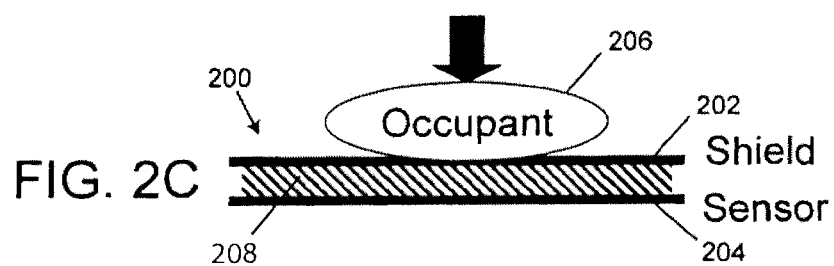
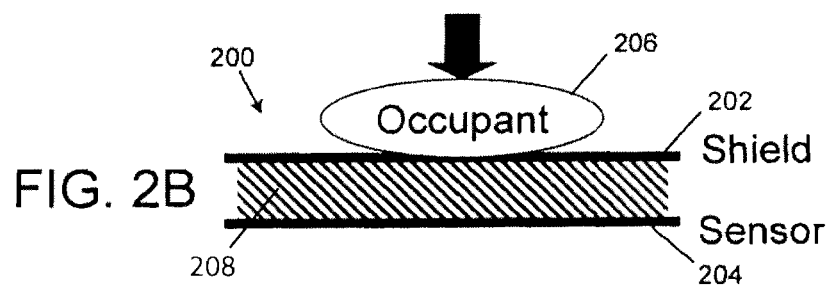
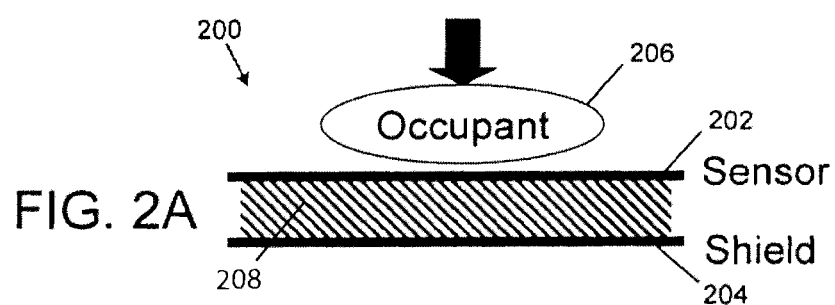
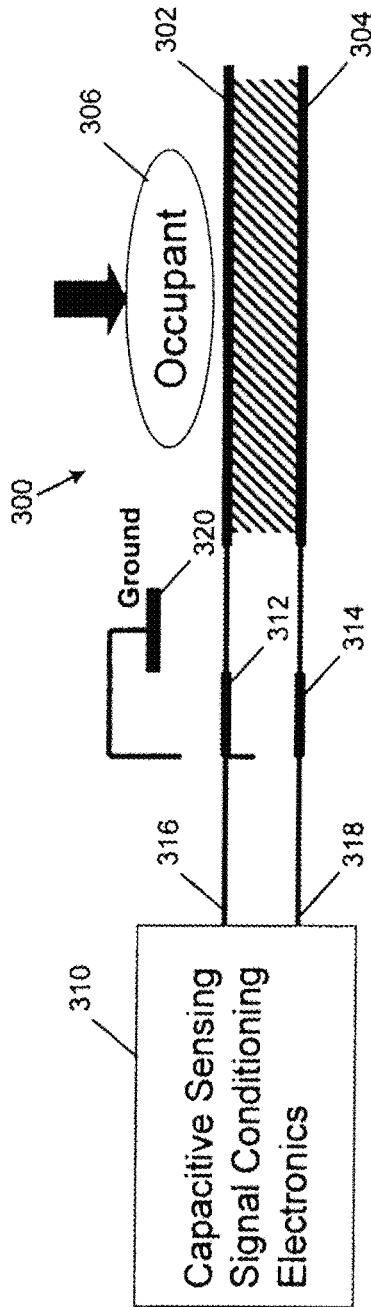
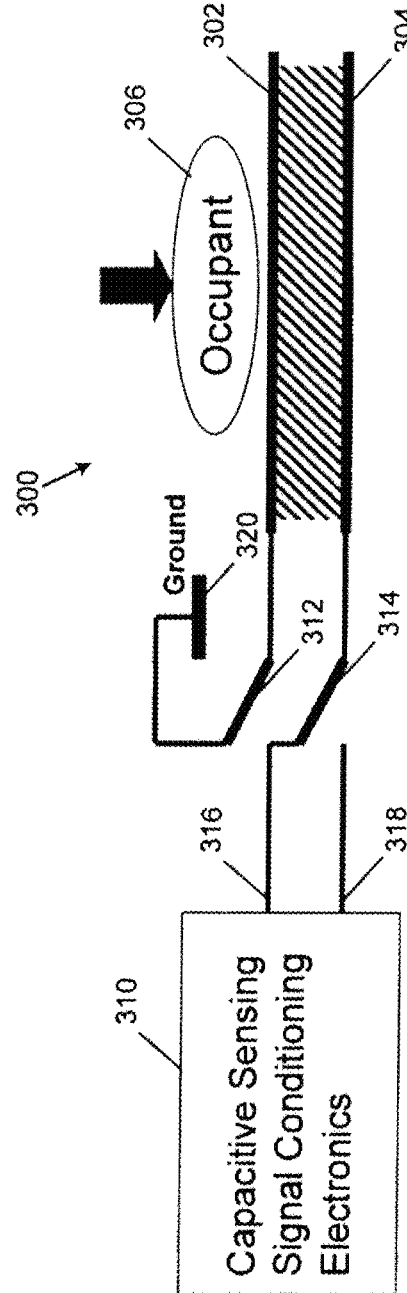


FIG. 1





**Occupant  
Sensing  
Configuration**



**Weight  
Sensing  
Configuration**

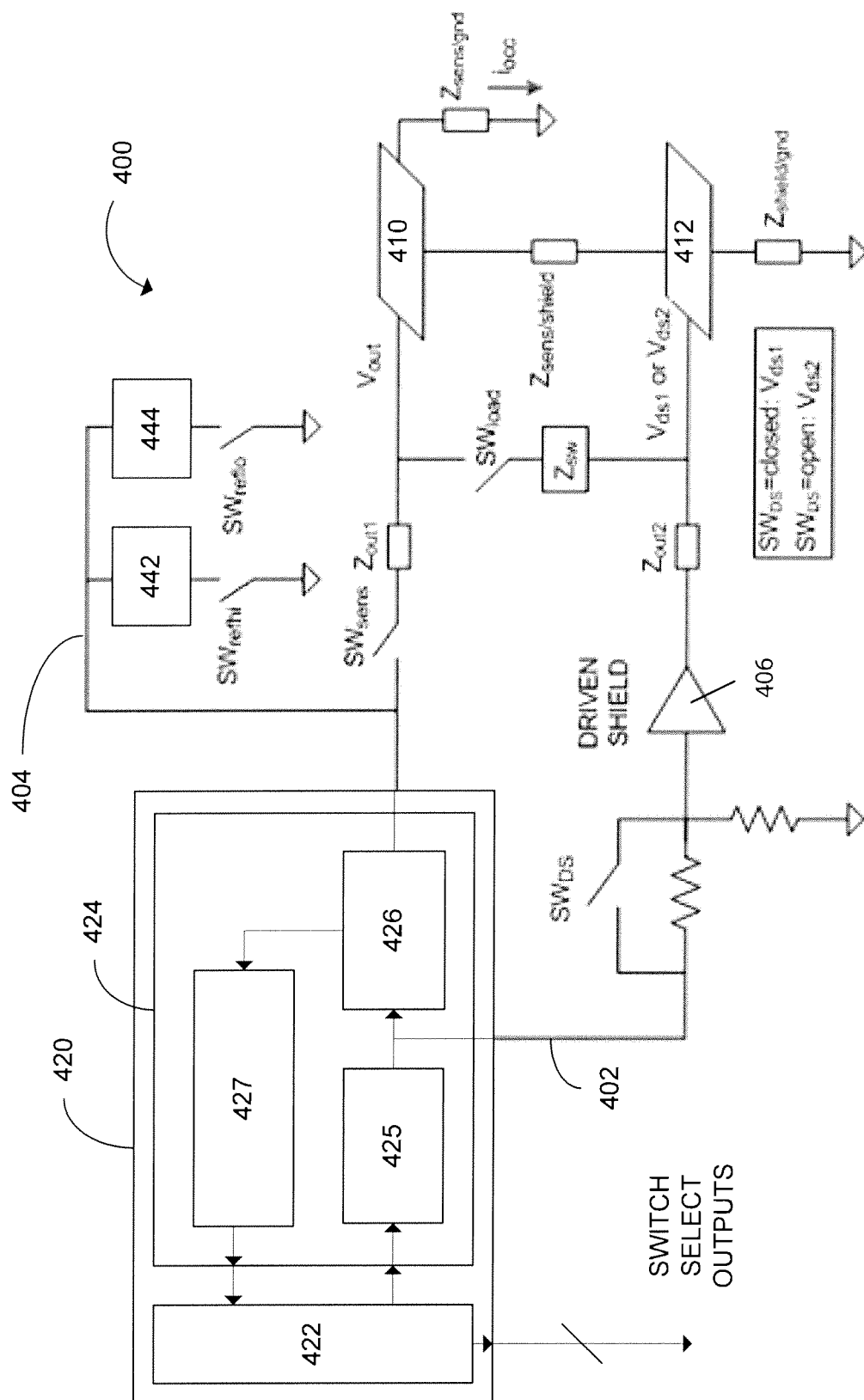


FIG. 4

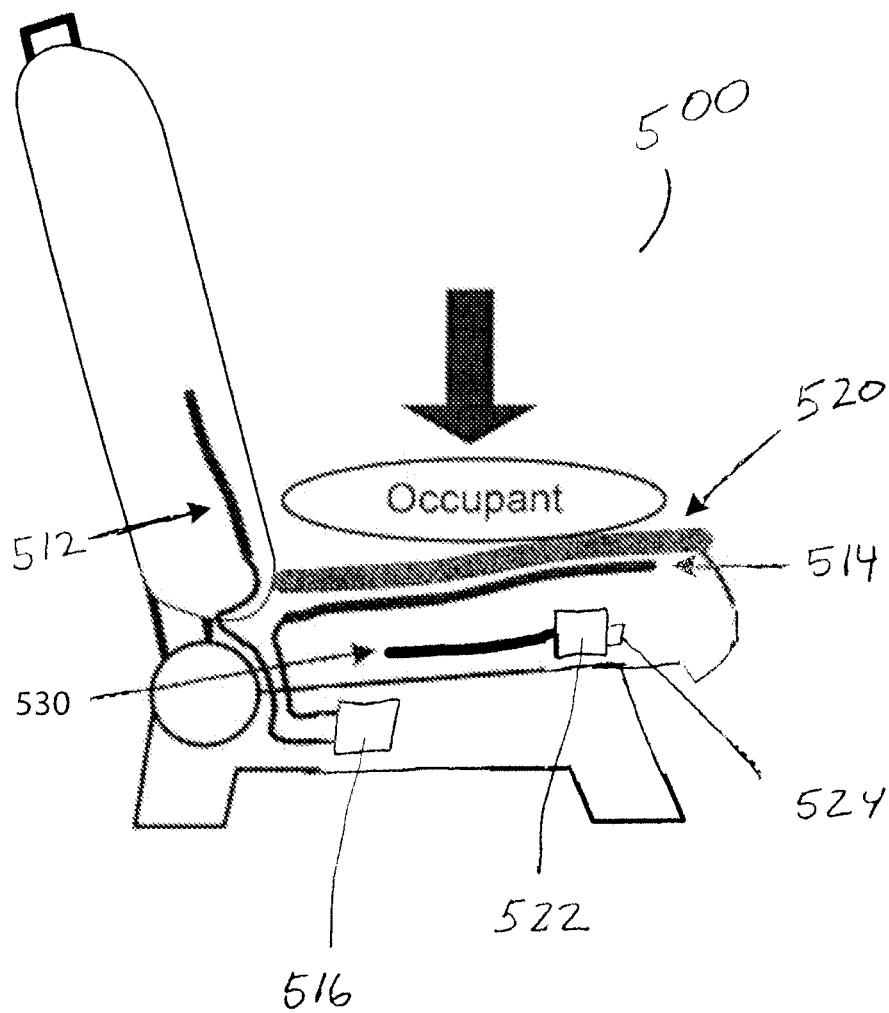


FIG. 5

1

## OCCUPANT DETECTION AND CLASSIFICATION SYSTEM

### CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation in part of U.S. patent application Ser. No. 12/949,729 filed Nov. 18, 2010 (now U.S. Pat. No. 8,896,326) and also claims priority to and the benefit of U.S. Provisional Patent Application No. 61/272,928, filed Nov. 19, 2009. The foregoing applications are incorporated by reference herein.

### BACKGROUND

The present disclosure relates generally to the field of capacitive sensing systems and sensing methods. More specifically, the disclosure relates to capacitive sensing systems and sensing methods for a vehicle seat.

There is a need for a system and method for accurate differentiation of an occupant from an object placed on a seat in an occupant classification system.

### BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will become apparent from the following description and the accompanying exemplary embodiments shown in the drawings, which are briefly described below.

FIG. 1 is a schematic diagram of a vehicle seat, according to an exemplary embodiment.

FIGS. 2A-2C are schematic diagrams of a capacitive sensing system, according to an exemplary embodiment.

FIGS. 3A and 3B are schematic diagrams of a capacitive sensing system, according to another exemplary embodiment.

FIG. 4 is a circuit diagram of the occupant detection system according to one exemplary embodiment.

FIG. 5 is a schematic drawing of a vehicle seat including a seat heater and an occupant detection system.

### DETAILED DESCRIPTION

The figures illustrate the exemplary embodiments in detail. However, it should be understood that the application is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology is for the purpose of description only and should not be regarded as limiting.

A capacitive or electric field type sensor for use in an occupant classification system or occupant sensing system (for example, a system to detect occupancy of a vehicle seat) may be implemented in many ways. For example, according to one embodiment, an AC current may be provided to a sensing electrode located in a vehicle seat. The current or change in the current to the sensor may be measured and used as an indicator of the impedance from the sensing electrode to ground. In certain vehicle seat configurations, a seat heater may be provided. According to one embodiment of an occupant sensing system, an electrode may function as both a capacitive sensing electrode and a seat heater.

In an occupant classification system, the occupant is classified using information from sensors that sense characteristics about the object located on a vehicle seat. Some systems sense the total weight on the seat. When a capacitive sensor is used to classify the occupant, the environment above the seat cover is sensed using various techniques to identify the

2

dielectric and conductive properties of the occupant. A conductive sensing element is placed in the seat and, according to one embodiment, the impedance from the electrode to ground may be used as an indicator of the occupant situation above the seat cover.

The occupant detection and classification system is configured so that the environment below the seating surface does not influence the classification of the occupant. When a seat heater is provided, typically a resistive heater is employed. A resistive heater is essentially a grounded wire or conductor located in the vehicle seat. The sensing electrode for an occupant classification and detection system may be placed above the seat heater. If the orientation between the sensing electrode and the heater changes, the offset capacitance will change and the change may result in a negative impact on the ability of the system to accurately classify the occupant. For example, the detection system may be configured to include an offset for the measurement of an empty seat conduction. If the empty seat offset of the measurement drifts significantly (e.g., due to a change in orientation of the electrode and heater), the system may not accurately classify the occupant.

According to various exemplary embodiments, a sensing system for automotive occupant classification may use various conductors in the seat as sensing electrodes. For example, the sensing system may include a "sensor" conductor or assembly located above a "shield" conductor. The shield conductor is configured to reduce sensitivity of the sensing system to or interference from objects below the shield (e.g., seat pan, seat heater, etc.). Due to the provision of a shield electrode, the occupant sensing system may be maintained in the same sensing configuration for sensing objects above the seat while the shield prevents the system from sensing of objects below the sensing electrode. A capacitive sensing occupant classification system may use the measurements obtained from a sensing electrode to classify the occupant of a vehicle seat, and to determine whether to remind the occupant to buckle their seat belt.

According to other exemplary embodiments, a sensing system may use multiple electrodes on opposite sides of a thick piece of foam. Measurements may be made while the electrodes are in various configurations. According to still other exemplary embodiments, a sensing system may combine or integrate weight sensing concepts with capacitive sensing concepts into a single system. The integrated system may use weight/pressure information along with capacitive information to identify the occupant situation and produce a preferred classification.

According to various exemplary embodiments, a sensing system may use electronic methods for making capacitive measurements (e.g., using high frequency current measurements or other methods). The sensor assembly materials may include any type of conductive material for the electrodes (e.g., copper, conductive inks, conductive fabrics, etc.) and any compressible material for the spacer between the sensor and the shield (e.g., non-woven felts, woven materials, foams, materials used to allow air flow for forced air climate control seats, or any other material that will significantly compress at pressures under 1 psi).

Referring generally to the figures, an occupant classification system is described that uses a sensor (e.g., a capacitive vehicle sensor) to detect seat occupancy and to detect a weight on the seat. The occupant classification system may generally include a sensor and a shield. For occupant sensing, the sensor may be oriented above the shield to reduce the influence of objects located under the shield (e.g., a seat heater) on sensor measurements. The classification system may include a weight or force sensing capability. When sensing



the weight, the sensor and shield may switch orientations (e.g., via electronic switching) with the sensor oriented below the shield to reduce the influence objects placed on top of the seat (e.g., electronic devices) have on sensor measurements. The occupant sensing and weight or force sensing measurements may be used together to determine whether an object on the seat is a person and may reduce the false detection of objects as people.

Referring to FIG. 1, a vehicle 10 is shown with an occupant 12 in a seat 14 of the vehicle 10, according to an exemplary embodiment. The seat 14 may include an occupant classification and detection system 16. As shown in FIG. 1, the occupant classification system 16 may generally be located in the seat 14 below the area in which an occupant 12 of the vehicle 10 sits, or may be located in other areas of the seat 14 or vehicle 10.

The occupant classification system 16 may generally include a sensor, a shield, and electronics for sensing and classifying the occupancy of the seat 14. For example, the sensor may be used to provide measurements that correspond to the effect of an object on the sensor due to both the conductivity and weight of the object. Measurements from the sensor may be evaluated to determine the existence of an object or occupant in the seat 14. The occupant classification system 16 may include or be configured to operate in conjunction with a seat heating system and/or other systems for the seat 14 of the vehicle 10.

The occupant classification system 16 includes a capacitive or electric field sensor that includes a sensing electrode. The capacitive sensor may generally be capable of sensing properties such as a proximity, position, or weight of an object, or the like. Various measurements from the sensing electrode may be used to detect the presence of an object in the seat. For example, the system may measure the change in capacitance (e.g., changes in an electrical property between two conductive objects). As an occupant 12 sits on seat 14, the system may detect a capacitance change to determine the presence of the occupant 12 by the occupant classification system 16.

According to one embodiment, as shown in FIG. 2A, a capacitive based occupant classification system 200 includes an upper electrode 202 and a lower planar electrode 204. In the embodiment of FIG. 2A, the upper planar electrode 202 is a sensing electrode 202 and the lower planar electrode 204 is a shield electrode. During a typical or normal measurement mode or configuration, the system 200 detects changes in the signal from the sensing electrode—the upper electrode 202 closest to an occupant 206—to determine whether an occupant is present. The shield electrode (the lower electrode 204) is located below the sensing electrode in a vehicle seat. The sensing electrode and the shield electrode may be changed to different configurations to measure the force on the surface of the seat.

Referring to FIG. 2B, in one exemplary embodiment, the role or function of the sensing electrode and the shield electrode may be switched when the occupant classification and detection system is operated in a force or weight measurement mode. In the weight measurement mode, the system 200 may be configured to be less sensitive to the presence of the occupant and may be used to determine the weight of the occupant 206. During the weight measurement mode, capacitive or electric field sensing is performed using the measurements obtained from the lower electrode 204 furthest from the occupant (the shield electrode in the occupant sensing measurement) and the upper electrode 202 closest to the occupant 206 is switched to become the shield electrode. The electrodes 202, 204 may be switched using electronic or mechanical switches configured to modify the current flow through

the electrodes. Instead of using the lower sensing electrode to measure the presence of the occupant, in the force or weight measurement mode, the system's electronics and/or software may be configured to measure the capacitance (or current or impedance) between the sensor and the shield (the electrodes 202, 204). The measured capacitance (or a measure representative or related to the capacitance or current or impedance) may be compared to a threshold value. A difference between the measured value and the threshold value can be attributed to a change in relative location of the sensors due to a force on the seat. The measurement may be made without being significantly influenced by the conductive or dielectric characteristics of the occupant 206 because the occupant 206 is shielded from the measurement by the upper electrode 202.

Referring to FIG. 2C, as the force on the seat bottom is increased, material 208 between the sensor (electrode 204) and the shield (electrode 202) is compressed. This compression causes the electrodes 202, 204 to move closer together causing a corresponding increase in the capacitance between the two electrodes 202, 204. The capacitance between the electrodes 202, 204 (or any other measure that is an indication of the change in relative position between the electrodes 202, 204) may be used to estimate the force on the seat applied by the occupant 206. The force on the seat may be used to differentiate between an occupant (i.e., person) and an inanimate object (e.g., computer).

FIGS. 3A and 3B disclose another exemplary embodiment of a capacitive or electric field type occupant classification and detection system. The system 300 shown in FIGS. 3A and 3B is similar to the system 200 of FIGS. 2A-2C and includes an upper electrode 302 and a lower electrode 304 for sensing an occupant 306. The system 300 further includes electronics 310 (e.g., sensing and signal conditioning electronics) configured to provide current or signals to drive the electrodes 302, 304 and to provide measurements on the electrodes 302, 304.

The occupant classification and detection systems disclosed herein may include a controller, processor or electronic control unit (ECU) that controls the system and receives various measurements from the system components (e.g., the sensing electrodes). The controller is configured to interact with other vehicle systems such as, for example, vehicle safety systems (e.g., airbag and seat belt systems). The controller may provide a signal to a vehicle safety system that indicates whether an adult person is located in the vehicle seat so that safety devices may be activated if appropriate. The controller for the occupant classification system may be integrated with a controller for another vehicle system such as, for example, the controller used for a vehicle safety system.

Referring specifically to FIG. 3A, the system 300 includes an occupant sensing mode or configuration for detecting the occupant 306 while shielding interference from below the system 300, according to one exemplary embodiment. System 300 includes a switch 312 that electrically couples the upper electrode 302 to a sensing port 316 of the electronics 310 and includes a switch 314 that electrically couples the lower electrode 304 to a shield port 318 of the electronics 310. In the configuration of FIG. 3A, the upper electrode 302 is the sensing electrode and the lower electrode 304 is the shield electrode.

Referring now to FIG. 3B, the system 300 also includes a weight or force sensing mode or configuration that reduces sensitivity to electrical properties of the occupant 306 and may be used for determining the weight of the occupant 306, according to one exemplary embodiment. In the embodiment of FIG. 3B, the conductor or upper electrode 302 near the occupant 306 is switched to ground 320 and the conductor or

lower electrode **304** away from the occupant **306** is switched to the sensing port **316** of the electronics **310**. In the configuration of FIG. 3B, the upper electrode **302** is the shield electrode and the lower electrode **304** is the sensing electrode.

The electronics **310** employed by the system may be software and any analog or digital circuitry capable of controlling the occupant classification system **300**. Also, according to various exemplary embodiments, the switches **312**, **314** may be any electronic or mechanically actuated switches capable of modifying a flow of electrical current. The electronics **310** may be configured to control the switching of the switches **312**, **314**. For example, the system **300** may generally be in an occupant sensing configuration and only switch to a weight sensing configuration for verification if the sensing configuration determined the occupant to be of adult size. Alternatively, the switching may occur periodically at a time interval.

The addition of a weight or force measurement to the electric field or capacitive measurement allows the system to separate or discriminate between cases where an object may look large (e.g. appear like an adult) to the capacitive sensing system **200**, **300**, but is physically small. For example, capacitive loading or electrical interference generated by electronic devices on the seat, especially when those devices are plugged into the 12 volt accessory plug in the vehicle, may cause an increase in measured capacitance when the sensing node is positioned above the shield node. Such electronic devices may include cellular phones, smart phones, personal digital assistants (PDAs), global positioning systems (GPS), optical disc (e.g., DVD, Blu-Ray, etc.) players, laptop computers, or any other electronic device. Electronic devices may appear large to the capacitive sensor because they are conductors and are well coupled to ground. Recognizing electronic devices or other objects on the seat incorrectly as adults may cause an annoyance when the vehicle seat belt reminder turns on. The exemplary embodiments described above solve the annoyance issue by integrating a low cost force measurement into a capacitive sensing system. The weight sensing configuration may also be used to identify the empty seat and diagnose problems with the capacitive sensing system and the same measurement electronics and connections out to the sensor may be used for the weight measurement and the capacitive measurement, resulting in a low cost solution.

The exemplary embodiments of FIGS. 2 and 3 may use any configuration of electrodes where the change in relative physical location of the sensor to shield is measured electronically and is not influenced significantly by the conductive or dielectric characteristics of the occupant. According to alternative exemplary embodiments, instead of detecting the capacitance between the sensor and shield electrodes, the system may use multiple measurements in multiple configurations to calculate a high frequency (e.g., about 100 kHz, greater than 100 kHz, etc.) AC current flowing only between the sensor and shield. A significant increase in that measured current indicates an increase in the sensor to shield capacitance, which indicates a change in relative position of the sensor and shield due to an increased force from the occupant. According to other examples, the capacitance between the sensor and shield electrodes may be measured by analyzing a change in an RC time constant, a change in a response of the system to a step voltage to the electrodes, a change in charge sharing between the electrodes, or any other method of measuring capacitance.

FIG. 4 depicts a representative or exemplary circuit diagram of an occupant detection system **400** according to one exemplary embodiment. The occupant detection system **400** includes a sensing circuit **402** electrically connecting the sensing electrode **410**, the shield electrode **412**, switches

$SW_{DS}$  and  $SW_{load}$ , and electronics **420**. The sensing circuit **402** may also include a signal producing device **406**, such as an amplifier or transistor, disposed between electronics **420** and the shield electrode **412**. The sensing electrode **410** may also include a conductor, sensing node, or other device, such as an inductor, disposed outside the electronics **420**. The shield electrode **412** may also include a conductor or other device, such as a shield node, disposed between the shield electrode **412** and signal producing device **406**. While the sensing circuit **402** is shown outside the electronics **420**, the electronics **420** may include components of the sensing circuit **402**, such as switches, amplifiers, or other devices. For example, the electronics **420** and components of the sensing circuit **402** may be integral, disposed in a common housing, or on a common circuit board, while the sensing and shield electrodes **410**, **412** are external to the housing and electrically coupled to the electronics **420**. Those skilled in the art, however, will recognize that other configurations are possible according to other embodiments.

The electronics **420** generally include a controller **422** and a signal conditioning device **424**. The signal conditioning device **424** generally includes a sine wave output device **425**, a current sense circuitry **426**, and a demodulation and filtering device **427**. The signal conditioning device **424** produces an output signal, measures current, and produces an input signal corresponding to the measured current.

The controller **422** may be a microprocessor or electronic control unit (ECU) and controls the occupant detection system **400**. The controller **422** determines when the signal conditioning device **424** produces an output signal, opens and closes the switches  $SW_{DS}$  and  $SW_{load}$ , and interprets the input signal received from signal conditioning device

As described further below, the system **400** may be operated to obtain certain measurements that may be used to obtain a representative indication of the force on the vehicle seat, such as when the occupant's weight forces the sensing electrode **410** toward the shield electrode **412**. The electronics **420** are used to calculate the impedance between the sensing electrode **410** and shield electrode **412**, which can be used to classify the occupant. The electronics **420** may also be used to calculate the impedance between the sensing electrode **410** and ground, which can be used to detect an occupant. The electronics **420** may also be used to calculate the impedances between the sensing electrode **410** and both the shield electrode **412** and ground to both detect and classify an occupant.

The controller **422** may be a microprocessor or electronic control unit (ECU) and controls the occupant detection system **400**. The controller **422** determines when the signal conditioning device **424** produces an output signal, opens and closes the switches  $SW_{DS}$  and  $SW_{load}$ , and interprets the input signal received from signal conditioning device **424**.

By opening and closing the switches  $SW_{DS}$  and  $SW_{load}$ , the sensing circuit **402** of the occupant detection system **400** may be placed in four different configurations (i.e., switches  $SW_{DS}$  and  $SW_{load}$ , respectively, are closed/open, closed/closed, open/open, and open/closed). Closing  $SW_{DS}$  changes the amplitude of the output signal on the shield electrode **412**, and closing  $SW_{load}$  introduces an impedance  $Z_{SW}$  between the sensor and shield electrodes **410**, **412**.

In each of the four circuit configurations, current is measured by the signal conditioning device **424**, thus providing four current measurements  $M_1$ ,  $M_2$ ,  $M_3$ , and  $M_4$ .  $M_1$  is measured when  $SW_{DS}$  is closed and  $SW_{load}$  is open,  $M_2$  is measured when  $SW_{DS}$  is closed and  $SW_{load}$  is closed,  $M_3$  is measured when  $SW_{DS}$  is open and  $SW_{load}$  is open, and  $M_4$  is measured when  $SW_{DS}$  is open and  $SW_{load}$  is closed.

7

From these four current measurements, a number proportional to the impedance between the sensing electrode **410** and shield electrode **412** (i.e., a force value) is calculated by the controller **422** as follows:

$$\frac{-Z_{\text{sens}/\text{shield}}}{Z_{\text{SW}}} = \left( \frac{M_4 - M_2 - M_3 + M_1}{M_1 - M_3} \right)$$

This equation is derived from the following equations:

$$\begin{aligned} M_1 &= \left( \frac{V_{\text{out}} - V_{\text{ds1}}}{Z_{\text{sens}/\text{shield}}} + \frac{V_{\text{out}}}{Z_{\text{sens}/\text{ground}}} \right) \\ M_2 &= \left( \frac{V_{\text{out}} - V_{\text{ds1}}}{Z_{\text{sens}/\text{shield}}} + \frac{V_{\text{out}}}{Z_{\text{sens}/\text{ground}}} + \frac{V_{\text{out}} - V_{\text{ds1}}}{Z_{\text{SW}}} \right) \\ M_3 &= \left( \frac{V_{\text{out}} - V_{\text{ds2}}}{Z_{\text{sens}/\text{shield}}} + \frac{V_{\text{out}}}{Z_{\text{sens}/\text{ground}}} \right) \\ M_4 &= \left( \frac{V_{\text{out}} - V_{\text{ds2}}}{Z_{\text{sens}/\text{shield}}} + \frac{V_{\text{out}}}{Z_{\text{sens}/\text{ground}}} + \frac{V_{\text{out}} - V_{\text{ds2}}}{Z_{\text{SW}}} \right) \end{aligned}$$

$$\frac{-Z_{\text{sens}/\text{shield}}}{Z_{\text{SW}}},$$

The number thus, is proportional to the impedance between the sensing electrode **410** and the shield electrode **412** and may be used to determine the relative force on the vehicle seat in order to classify the occupant. The resulting occupant classification may be used, for example, to determine whether the seatbelt reminder should be turned on or whether an airbag should deploy.

From current measurements  $M_1$ ,  $M_2$ ,  $M_3$ , and  $M_4$ , a number corresponding to the impedance between the sensing electrode **410** and ground (i.e., a detection value) may also be calculated as follows:

$$i_{\text{occ}} = \frac{(M_1 \times M_4) - (M_2 \times M_3)}{M_1 + M_4 - M_2 - M_3}$$

This equation is derived from the following equations:

$$\begin{aligned} M_1 &= i_{\text{occ}} + \left( \frac{1 - V_{\text{ds1}}}{Z_{\text{sens}/\text{shield}}} \right) \\ M_2 &= i_{\text{occ}} + \left( \frac{1 - V_{\text{ds1}}}{Z_{\text{sens}/\text{shield}}} \right) + \left( \frac{1 - V_{\text{ds1}}}{Z_{\text{SW}}} \right) \\ M_3 &= i_{\text{occ}} + \left( \frac{1 - V_{\text{ds2}}}{Z_{\text{sens}/\text{shield}}} \right) \\ M_4 &= i_{\text{occ}} + \left( \frac{1 - V_{\text{ds12}}}{Z_{\text{sens}/\text{shield}}} \right) + \left( \frac{1 - V_{\text{ds2}}}{Z_{\text{SW}}} \right) \end{aligned}$$

where  $Z_{\text{SW}}$  is cancelled out and need not be known, but should be large enough to meaningfully change the calculations, and  $Z_{\text{sens}/\text{shield}}$  is derived from the equation for

$$\frac{-Z_{\text{sens}/\text{shield}}}{Z_{\text{SW}}}$$

8

above. The value for  $i_{\text{occ}}$  corresponds to (i.e., is inversely proportional to) the impedance between the sensing electrode **410** and ground and may be used to determine the presence of the occupant or an object (i.e., detect an occupant).

According to one exemplary embodiment, the occupant detection system may also include a normalization circuit **404**. The normalization circuit **404** enables the electronics **420** to adjust for measurement variations due changes in gain, offset shift and phase shift in the sensing circuit **402**.

The normalization circuit **404** includes a high reference impedance device **442** and a low reference impedance device **444**, each having a different, known impedance. Corresponding switches  $\text{SW}_{\text{refhi}}$  and  $\text{SW}_{\text{reflo}}$  selectively connect the high and low reference impedance devices **442**, **444**, respectively, to ground. The signal conditioning device **424** produces a 100 kHz, as an example, AC current at constant voltage and measures reference currents  $M_{\text{refhi}}$  and  $M_{\text{reflo}}$ . Reference current measured when  $\text{SW}_{\text{refhi}}$  is closed and  $\text{SW}_{\text{reflo}}$  is open, and reference current  $M_{\text{refhi}}$  is measured when  $\text{SW}_{\text{refhi}}$  is open and  $\text{SW}_{\text{reflo}}$  is closed.

The sensing circuit **402** is provided with a switch  $\text{SW}_{\text{sens}}$  to isolate the sensing circuit **402** and normalization circuit **404**. When current measurements  $M_1$ ,  $M_2$ ,  $M_3$ , and  $M_4$  are taken,  $\text{SW}_{\text{sens}}$  is closed. When reference currents  $M_{\text{refhi}}$  and  $M_{\text{reflo}}$  are taken,  $\text{SW}_{\text{sens}}$  is open, thus isolating the normalization circuit **404** from the sensing circuit **402**.

By measuring reference currents  $M_{\text{refhi}}$  and  $M_{\text{reflo}}$  with respect to impedance devices **442**, **444** of known impedance and isolating the normalization circuit **404** from the sensing circuit **402**, the microprocessor **422** may calculate system impedance independent of the sensing circuit **402**. In this manner, the microprocessor **422** may account for changes in gain, offset shift and phase shift in the sensing circuit **402** more accurately detect and classify the occupant.

According to various exemplary embodiments, the shield may be driven with any potential or signal that is compatible with the measurement concepts and the associated electronics hardware. For example, the shield may be driven with a signal that is similar to or the same as the sensor signal, may be connected to a fixed DC level, or may be driven with various signals to enable the multiple measurement concept mentioned above.

Although the occupant classification system **200**, **300** is illustrated as including multiple features utilized in conjunction with one another, the system **200**, **300** may alternatively utilize more or less than all of the noted mechanisms or features. For example, in other exemplary embodiments, the more electrodes may be used in the system **200**, **300**.

FIG. **5** discloses a occupant sensing and classification system **500**. The system **500** incorporates elements of the system described above. The system **500** may include a seat heater. The seat heater may include a seat back heating element **512** and/or a seat bottom heating element **514**. The seat bottom heating element **514** is located beneath a seat cover or seat pad **520**. The heating elements may be controlled by a seat heater controller **516**. Alternatively, the same controller could be used for control of both occupant detection and sensing and the seat heater.

The system **500** includes a sensing mat **530** that includes a sensing electrode and a shield electrode separated by a compressible material. The sensing mat **530** is placed in the seat bottom, ideally underneath the seat foam. The sensor would measure weight or force on the seat by calculating the impedance between the sensing electrode and shield electrode using the electronics **310** described above with regard to the weight sensing mode. According to this embodiment of the system **500**, the occupant sensing configuration (i.e., capacitance

based measurement of the sensing electrode) would not be required. Occupant detection would be conducted primarily based on the force or weight sensing measurements and calculations. For example, the occupant of the seat would be determined when the measure of force exceeds a threshold value corresponding to a particular sized occupant. In one embodiment, the actual weight of the occupant need not be determined as the measures of impedance between the sensing and shield electrodes could be used to correlate to a particular sized occupant.

The system 500 includes a controller 522 for controlling the signal (e.g., voltage or current) provided to the sensor mat 520 and the sensing and shield electrodes. The controller 522 is configured to perform the occupant classification and/or detection determinations and provide a corresponding signal to other vehicle systems and subsystems via a bus or other electrical connection. The controller 522 may be connected to the vehicle communication bus via a connection 524.

According to an alternative embodiment, measurements obtained using the occupant sensing configuration and corresponding signal processing could be used in order to determine a wet seat condition. Seat wetness could affect the measurement obtained in the weight sensing configuration. Determination of a wet seat condition could be used to make a corresponding adjustment to the calculations performed on the measurements obtained using the seat wetness may be necessary information as seat wetness would affect the sensor to shield measurement. Use of electric field or capacitive type sensing to detect a wet seat condition is disclosed for example in U.S. Patent Publication 2007/0192007 (incorporated by reference herein).

The above described force or weight based occupant detection system 500 may operate in conjunction with a seat belt tension sensor. For example, as described in U.S. Pat. No. 6,260,879 (incorporated by reference herein), the force exerted downwardly onto the vehicle seat may result from two different components. One component is attributable to the mass of the occupant, and another component may be the force attributable to the tension present in the vehicle seat belt. A seat belt tension measurement sensor may be provided to determine the amount of force acting downwardly on the vehicle seat as a result of seat belt tension. The tension in the seat belt as measured by the seat belt tension sensor provides an indication of the presence of a tightly belted child seat or other object.

Although specific shapes of each element have been set forth in the drawings, each element may be of any other shape that facilitates the function to be performed by that element. For example, the electrodes have been shown to be planar electrodes, however, in other exemplary embodiments the structure may define electrodes of other shapes. Further, while a specific form of switches has been shown in FIG. 3, according to other exemplary embodiments, the switches may be in other forms or actuate in different directions. The sensing and classification system described in detail above, may be employed with existing occupant detection systems such as those described in U.S. patent application Ser. No. 12/541,825 (now U.S. Pat. No. 8,138,772). The foregoing patent application is incorporated by reference herein in its entirety.

For purposes of this disclosure, the term "coupled" means the joining of two components (electrical, mechanical, or magnetic) directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two components (electrical or mechanical) and any additional intermediate members being integrally defined as a single unitary body with one another or

with the two components or the two components and any additional member being attached to one another. Such joining may be permanent in nature or alternatively may be removable or releasable in nature

The present disclosure has been described with reference to example embodiments, however persons skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

It is also important to note that the construction and arrangement of the elements of the system as shown in the preferred and other exemplary embodiments is illustrative only. Although only a certain number of embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements shown as multiple parts may be integrally formed, the operation of the assemblies may be reversed or otherwise varied, the length or width of the structures and/or members or connectors or other elements of the system may be varied, the nature or number of adjustment or attachment positions provided between the elements may be varied. It should be noted that the elements and/or assemblies of the system may be constructed from any of a wide variety of materials that provide sufficient strength or durability. Accordingly, all such modifications are intended to be included within the scope of the present disclosure. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the preferred and other exemplary embodiments without departing from the spirit of the present subject matter.

What is claimed is:

1. A system for detecting an occupant in a vehicle comprising:
    - a sensing electrode mountable in a seat bottom of a vehicle seat;
    - a shield electrode located in the vehicle seat below the sensing electrode;
    - a sensing circuit operatively coupled to the sensing electrode and the shield electrode;
    - a controller operatively coupled to the sensing circuit, wherein the controller operates to configure the sensing circuit to apply a plurality of signals to the shield electrode; and
    - a belt tension sensor operatively coupled to the controller and configured for measuring tension in a seatbelt;
- wherein the controller is configured to detect the presence of an object in the seat by detecting a relative force

## 11

applied to the seat by the object and by calculating a force value related to the impedance between the sensing electrode and the shield electrode by using the results of separate measurements performed when each of the plurality of signals are applied to the shield electrode; 5

wherein the controller is configured to classify the object based on a signal from the belt tension sensor;

wherein one of the plurality of signals is applied to the sensing electrode and wherein the controller is configured to detect the presence of a wet seat by calculating a detection value related to the impedance from the sensing electrode to ground; 10

wherein the plurality of signals include first, second and third signals and wherein the controller operates to configure the sensing circuit to apply the first signal to the sensing electrode and to alternately apply the second signal and the third signal to the shield electrode; 15

wherein the controller operates to configure the sensing circuit to alternately couple a plurality of impedances between the sensing electrode and the shield electrode; and wherein the separate measurements used in the calculation of the detection value and force value are taken when the coupling impedances are in different configurations; 20

wherein the separate measurements are first, second, third, and fourth current measurements, and wherein the first and second current measurements occur when the second signal is applied to the shield electrode and the third and fourth current measurements occur when the third signal is applied to the shield electrode; and 25

wherein the first and third current measurements occur when none of the plurality of impedances are coupled between the sensing electrode and shield electrode and the second and fourth current measurements occur when the plurality of impedances are coupled between the sensing electrode and shield electrode. 30

2. A system for detecting an occupant in a vehicle comprising: 35

a sensing electrode mountable in a seat bottom of a vehicle seat; 40

a shield electrode located in the vehicle seat below the sensing electrode;

## 12

a sensing circuit operatively coupled to the sensing electrode and the shield electrode;

a controller operatively coupled to the sensing circuit, wherein the controller operates to configure the sensing circuit to apply a plurality of signals to the shield electrode; 5

wherein the controller is configured to detect the presence of an object in the seat by detecting a relative force applied to the seat by the object and by calculating a force value related to the impedance between the sensing electrode and the shield electrode by using the results of separate measurements performed when each of the plurality of signals are applied to the shield electrode; 10

wherein one of the plurality of signals is applied to the sensing electrode and wherein the controller is configured to detect the presence of a wet seat by calculating a detection value related to the impedance from the sensing electrode to ground; 15

wherein the plurality of signals include first, second and third signals and wherein the controller operates to configure the sensing circuit to apply the first signal to the sensing electrode and to alternately apply the second signal and the third signal to the shield electrode; 20

wherein the controller operates to configure the sensing circuit to alternately couple a plurality of impedances between the sensing electrode and the shield electrode; and wherein the separate measurements used in the calculation of the detection value and force value are taken when the coupling impedances are in different configurations; 25

wherein the separate measurements are first, second, third, and fourth current measurements, and wherein the first and second current measurements occur when the second signal is applied to the shield electrode and the third and fourth current measurements occur when the third signal is applied to the shield electrode; and 30

wherein the first and third current measurements occur when none of the plurality of impedances are coupled between the sensing electrode and shield electrode and the second and fourth current measurements occur when the plurality of impedances are coupled between the sensing electrode and shield electrode. 35

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